Microcrustacean community structure in the different water bodies of the Lake Fertő/Neusiedler See (Fertő-Hanság National Park, Hungary): new invaders, recurring and missing taxa

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Abstract. The composition and community parameters of the microcrustacean assemblages were studied at twenty one sampling sites located in different water bodies/habitats (open water, inner ponds, canal, reed belt) of the shallow turbid alkaline Lake Fertő/Neusiedler See. 53 taxa (24 Cladocera, 9 Ostracoda, 20 Copepoda) were recorded from the lake, *Alona affinis* (Leydig, 1860) and *Eurytemora velox* (Lilljeborg, 1853) were detected for the first time. Including these two species, the microcrustacean fauna of the lake increased to 112 (49 Cladocera, 27 Ostracoda, 36 Copepoda) species on the basis of 15 published faunistic studies. Variations in composition, species richness, density, and diversity of communities of the different water bodies of the lake became obvious. In the reed belt, significant differences were detected between the species composition of the healthy and degraded reed stands. The long-term changes in the microcrustacean fauna are in accordance with the high instability and spatial variability of lake habitats and with several factors which are consequences of the extreme shallowness (water level fluctuations, extensive reed belt, high turbidity, wind effects, periodic anoxic conditions).

Keywords. Cladocera, Copepoda, Ostracoda, Neusiedler See

INTRODUCTION

Lake Fertő/Neusiedler See (47°42' N, 16°46' E) is the westernmost and largest steppe lake in Eurasia. It is situated on the Hungarian-Austrian border with a surface area of 309 km^2 (Hungarian part: 75 km^2), and a mean depth of 1.1 m. 54% of the whole lake and 85% of the Hungarian part is covered by reed. There are numerous reedless areas (inner ponds) of various sizes within the reed belt, which is intersected by artificial canals connecting the inner ponds with the open water areas. The Lake Fertő is a permanent, but extremely shallow lake with regulated outflow. According to the characteristic ionic ratios, the water of the lake is a mixed hydrogencarbonate-sulphate and sodium-magnesite water type. Its conductivity is 1.3–3.5 mS cm^{-1}, pH is 7.7–9.5 and its sulphate concentration is 350–500 mg l^{-1}. The water volumes and levels of the lake fluctuate significantly. Life conditions are highly influenced by the stirring effects of the primarily north and northwest winds. A detailed description of the lake is given in Löffler (1979).

The investigation of the microcrustacean fauna in the lake started in the 1890s by Daday (1890, 1891, 1897, 1900), who described 46 species (25 Cladocera, 11 Ostracoda, 10 Copepoda). Later Pesta (1954) recorded 18 cladoceran species and Zakovsek (1961) 16 microcrustacean species. Pesta established the importance of planktonic crustaceans in the lake, whereas Zakovsek was the first publising quantitative results about the zooplankton. 1979 was a prominently significant year for the microcrustacean studies. In the Austrian side of the lake, detailed investigations of the microcrustacean communities in the open water (Herzig 1979) and the reed belt (Löffler 1979) took place, whereas in the Hungarian part of the lake Ponyi & Dévai (1979) characterized the microcrustacean assemblages in the typical habi-

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tats of the lake. Herzig (1979) carried out a long-term (between 1968 and 1974) and intensive sampling design and provided a detailed description about the distribution, population and production biology of 7 Cladocera and 4 Copepoda species.

Between 1980 and 1982 Forró & Metz (1987) recorded 20 Cladocera and 14 Copepoda species from the reed belt of the Austrian part and revealed quantitative data of the assemblages. Kiss (2007a) summarized the faunistic works of the microcrustacean fauna, and reported 63 microcrustacean taxa in the period between 2002 and 2005. Out of the detected taxa 24 occurred in the inhomogeneous reed patches, situated near the Fertőrákos Bay, after the introduction of pre-treated wastewater. On the basis of the 15 studies on the microcrustacean fauna of the lake, 110 (48 Cladocera, 27 Ostracoda, 35 Copepoda) species were recorded between 1890 and 2005.

Between 2005 and 2012, our investigations continued, and our main objectives were to study the microcrustacean assemblages in the different habitats of the lake, and to examine the possible long-term changes in the composition of the fauna during the whole period (2002–2012).

MATERIALS AND METHODS

The study was carried out between 2002 and 2012, without sampling in 2007, 2008, and 2011. Sampling took place once a year, in the vegetation period, except for 2004, when four samplings (April, June, August, and October) were carried out. This sampling design is obviously unsuitable for the exploration of seasonal patterns, but it is capable of revealing the spatial differences of the habitats.

A total of 21 sampling sites were selected from all the typical water bodies of the lake: open water (sites 11, 20, 23, and 25), inner ponds (sites 41, 42, 44, 45, 46, 47, and 48), Bozi-canal (sites B1, B8, and B9), reed belt (sites 2, 3, 4, 5, 6, 7, and 9) (Fig. 1). The inner ponds are reedless areas within the reed belt. Their size varies between 0.5 and 42 ha, and their distance from the shore is also various. In the Hungarian part of the lake, the reed belt is intersected by canals (width max. 3 m), which connect the inner lakes with the open water areas (Dinka *et al.* 2004). For our research, we choose the longest (5.9 km), 2.5–3.0 m wide Bozi-canal, which crosses the whole reed belt. From the sampling sites in the reed belt, 2, 4, 5 and 9 are homogeneous, closed, healthy reed stands, while sites 3, 6 and 7 are degraded, loose reed stands.

Microcrustaceans were collected with plankton net (mesh size 70 μm, N = 1), by filtering 5 X 10 l of water then preserved in 4% formalin. The three examined groups of crustaceans were enumerated by using inverted microscopy, and with the exception of the harpacticoid copepods, were identified to species level. Microcrustacean abundance, including copepodids, was evaluated by enumerating individuals in the whole sample. Gulyás & Forró (1999, 2001), Meisch (2000) and the nomenclature of Dussart (1967, 1969) were used for species identification.

For comparing zooplankton assemblages, relative frequency and density for each species, the species richness (S), Shannon–Weaver diversity index (H′), dominance (D) and density of the assemblages were calculated. Microcrustacean composition, abundance, Shannon diversity, and dominance in the different water bodies were compared by Mann-Whitney test. The difference was considered to be significant when $P<0.05$. The composition of the healthy and degraded reed stands were compared by Detrended Correspondance Analysis using the PAST software (Hammer *et al.* 2001).

RESULTS AND DISCUSSION

Faunistic results

53 taxa (24 Cladocera, 9 Ostracoda, 20 Copepoda) were recorded, *Alona affinis* (Leydig, 1860) and *Eurytemora velox* (Lilljeborg, 1853) were recorded for the first time from the Lake Fertő (Appendix 1). Between 2002 and 2012, altogether

13 species were reported (see this survey and Kiss 2007a), which had not been mentioned earlier from the lake: 5 Cladocera (*Alona affinis*, *Alona intermedia* Sars, 1862, *Alonella nana* Baird, 1850, *Bunops serricaudata* (Daday, 1888), *Macrotrix rosea* (Liévin, 1848), *Pleuroxus truncatus* (O. F. Müller, 1785)), 4 Ostracoda (*Candona weltneri* Hartwig, 1899, *Fabaeformiscandona fragilis* (Hartwig, 1898), *Fabaeformiscandona holzkampfi* (Hartwig, 1900), *Pseudocandona compressa* (Koch, 1838)) and 4 Copepoda (*Eucyclops macruroides* (Lilljeborg, 1901), *Eurytemora velox, Macrocyclops distinctus* (Richard, 1887), *Paracyclops affinis* (Sars, 1863)). Out of the 13 taxa 9 occurred only in the inhomogeneous reed patch, after the introduction of pre-treated wastewater.

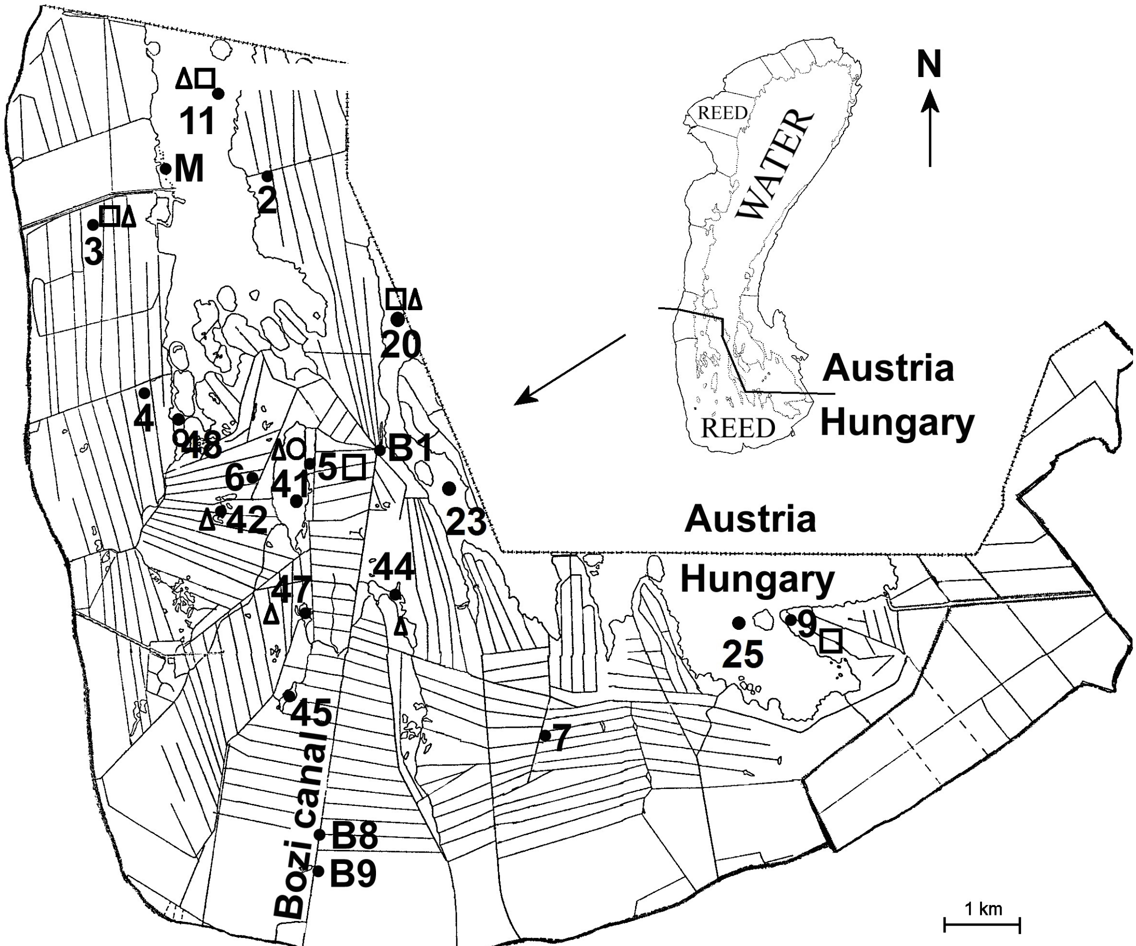

Figure 1. Sampling sites at the Lake Fertő/Neusiedler See and the distribution of *Eurytemora velox* in the different habitats in 2009 (○), 2010 (□) and 2012 (△).
M = Meteorological Station. Open water: sites 11, 20, 23, 25. Inner ponds: sites 41, 42, 44, 45, 46, 47. Bozi-canal: sites B1, B8, B9. Healthy reed stands: 2, 4, 5, 9. Degraded reed stands: 3, 6, 7.

Among the newly detected species, *Macrothrix rosea* (Löffler 1959, Metz & Forró 1991), *Eucyclops macruroides* (Löffler 1959) and *Paracyclops affinis* (Metz & Forró 1991) were known from the nearby Seewinkel (Eastern Austria), and *Candona weltneri*, *Pseudocandona compressa* and *Fabaeformiscandona fragilis* were detected in the neighbouring Lake Fehér in the Hanság (Kiss 2002a). In Hungary, the calanoid copepod *Eurytemora velox* has been known since 1992 (Forró

& Gulyás 1992), firstly from the area of the Szigetköz (Northwest Hungary) then it became widely distributed, for example in the Gemenc floodplain (Southern Hungary) (Kiss & Schöll 2009). In the Neusiedler See, this species occurred for the first time in 2009 then spread gradually and in 2012 a total of 492 specimens were collected (Fig. 1.)

The most abundant species of the lake were *Diaphanosoma mongolianum* and *Arctodiaptomus spinosus*. 17 out of the 53 species were found in all of the water bodies, while 12 occurred only in one type of habitat. Most taxa were detected from the Bozi-canal (39) and the reed belt (40). The composition, density, and diversity of the communities differed notably in the various water bodies of the lake (Fig. 2 and Appendix 1). These differences can be explained by the synergetic effects of physico-chemical and biological factors. Dinka *et al.* (2004) reported basic differences in the water chemistry of the different water type areas. The degree of these differences is essentially determined by distance from the open water areas and the water level of the given years. Somogyi *et al.* (2010) revealed the differences of phytoplankton composition and biomass of the open water, the inner ponds, and the canals. The inner ponds and the canals are more sheltered from wind-induced mixing, and therefore exhibit higher transparency. The presence of submerged and emerged macrophytes in the canals and the reed belt provide food and shelter against predators, but fish predation should not be ignored as an important eliminating factor in the lake (Herzig 1979).

The mean density of the communities was significantly higher in the inner ponds and canal sites than in the open water and the reed belt sites. Species richness and diversity increased from the open water sites to the canal and reed belt sites, while the values of dominance showed an opposite trend decreasing from open water to reed belt (Tab. 1.)

The mean annual density of the assemblages was significantly lower in 2002 (1.54 ind l^{-1}), 2009 (2.70 ind l^{-1}) and 2010 (3.57 ind l^{-1}) than the other years (2004: 13.56, 2005: 13.02, 2006: 22.01 and 2012: 10.62 ind l^{-1}). The extremely low water level of 2002 may explain the lowest recorded mean density. In the last years of the study, an interesting phenomenon were observed in the lake. Besides microcrustaceans, the abundance of fish assemblages also decreased and the colour of the lake water developed a reddish tinge, which is especially visible on the open lake on sunny days (pers. comm. of Dinka, M & Török, J.). This observed phenomenon supposedly refers to changes in the structure of the phytoplankton communities and in the bottom-up regulation, but further studies are needed to prove this relationship.

Table 1. Mean, minimum and maximum values of community parameters in the different water bodies of the Lake Fertő/Neusiedler See

	OPEN WATER (N=33)			**INNER PONDS (N=41)**			**BOZI CANAL (N=22)**			**REED BELT (N=25)**		
	MEAN	**MIN**	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**	**MIN**	**MAX**
density (ind 50 l^{-1})	376.9	33	2629	667.1	30	2739	768.3	33	6196	277.5	2	1633
Species richness	4.97	2	9	6.36	2	11	9.72	3	23	8.6	2	17
Shannon diversity (H)	0.92	0.31	1.88	1.07	0.3	1.79	1.37	0.31	2.51	1.34	0.31	2.15
Dominance (D)	0.49	0.17	0.77	0.46	0.19	0.95	0.37	0.12	0.86	0.38	0.14	0.85

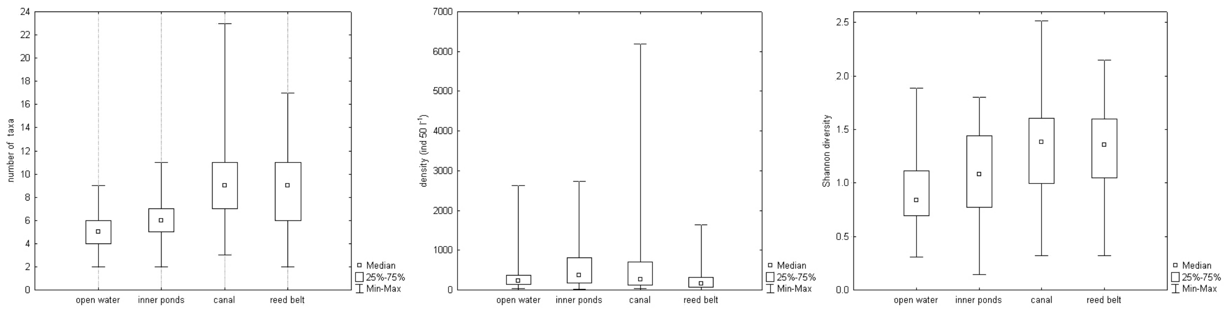

Figure 2. Microcrustacean species richness, density, and Shannon diversity at different water bodies of the Lake Fertő/Neusiedler See between 2002 and 2012.

Microcrustacean community structure in the different water bodies of the lake

Open water

30 taxa were recorded from the sampling sites of the open water (N=33). The mean density did not differ significantly between the four examined sampling sites. Similarly to the results of previous studies (Herzig 1979), the assemblages of the open water were characterized by the significant dominance of *Arctodiaptomus spinusus* and *Diaphanosoma*, and *Acanthocyclops vernalis* was also frequent in the Hungarian part of the lake (Ponyi & Dévai 1977, 1979). The presence and distribution of the *Diaphanosoma* genus in the lake is an interesting faunistic problem. Before 1990, *Diaphanosoma brachyurum* has been mentioned (Löffler 1979, Herzig 1979, Ponyi & Dévai 1977, 1979, Forró & Metz 1987), but Forró (1990) has already reported *Diaphanosoma mongolianum* as well. According to N. Korovchinsky (pers. comm., Forró 1990), only *D. mongolianum* is present in the lake.

Our results show that the abundance of *Diaphanosoma mongolianum* and *Arctodiaptomus spinosus* were the highest in the open water and these two species accounted for 57.4–99.5 per cent of the total microcrustacean standing stock, but notable differences could be found between the investigated years (Fig. 3). Interestingly, no specimens from the *Arctodiaptomus* genus occurred in the samples of 2009 and 2010. With the exception of *A. spinosus*, *D. mongolianum* and *Acanthocyclops vernalis*, the abundance of the other species of the open water was low, and the disappearance or low density of the phytophilous species was obvious in this water body type. Interestingly, one specimen of the rare benthic copepod, *Paracyclops fimbriatus* and the phytophilous cladoceran, *Pleuroxus truncatus* were collected at sampling sites of the open water.

The communities of the open water are primarily affected by the extreme turbidity and wind effects, which are typical features of the Lake Fertő. Increasing turbulence and turbidity have a negative influence on the feeding and development of zooplankton in the lake (Herzig & Koste 1989) and among extreme wind situations, the animals are crushed by the sediment particles. The direct effects of wind on plankton distribution have been demonstrated by Herzig (1979). According to his results, the major plankton density gradients were recorded along the wind axis.

Inner ponds

29 taxa were reported from the five examined inner ponds (N=41). Taxon richness was similar at the different sites. The new species of the lake, *Alona affinis* was only found in the inner ponds (in 2009, sites 47). The most frequent species were *Bosmina longirostris* (37 per cent of the total abundance in inner ponds), *Thermocyclops crassus* (15%) and, similarly to the open water sites, *Diaphanosoma mongolianum* (17%) and *Arctodiaptomus spinosus* (11%). The species rich-

ness and density of ostracods (the most frequent of them was *Limnocythere inopinata*) were higher than at the open water sites.

The abundance of the species varied in the different inner ponds. The density and relative frequency of *Thermocyclops crassus* was signifycantly higher in sites 47 and 48, *Acanthocyclops vernalis* in site 48 and *Ceriodaphnia quadrangula* in site 42. Ponyi & Dévai (1977, 1979) also mentioned the significant dominance of *Bosmina longirostris* in the inner ponds, but according to our results, *Thermocyclops crassus* was also frequent.

The inner ponds proved to be various in their physical and chemical aspects (Dinka *et al.* 2004) and this could partly explain the variation in the dominant species. Compared to the open water area, electrical conductivity and salt concentration were lower, and there are great differences in the transparency of the sites.

Canal

From the three sampling sites of the canal 38 taxa were detected (N=22). *Macrothrix hirsutecornis*, *Ectocyclops phaleratus*, *Eucyclops macrorus*, *E. macruroides* and *Microcyclops varicans* were only found at the sampling sites of the Bozi-canal. The abundance of *Daphnia pulex* was significantly higher in the canal than in the other water bodies. It should be noted, that all the three Hungarian representatives of the genus *Macrocyclops* were recorded from the canal. During the sampling period, the mean taxon richness, density and diversity as well as the maximum number of taxa (23 taxa, site B8, 05. 2005), the maximum density (123.9 ind l^{-1}, site B8, 07. 2006) and maximum diversity (2.51, site B8, 05. 2005) were the highest in the canal. The number of collected species in the canal increased from open water to reed belt (21, 29, 32 taxa).

The composition of the communities was different in the three sampling sites of the canal. A few specimens of *Moina brachiata* and *Leydigia acanthocercoides* occurred only at the entrance of the canal (site B1). *Moina brachiata* was collected only in 2003 and 2004 in very low density (Fig. 3.). At the inner sites of the canal (sites B8, B9), the species richness of the phytophilous taxa (especially cladocerans and ostracods) was higher than at the entrance of the canal. At the entrance of the canal (B1), the mean density and relative frequency of the pelagic *Diaphanosoma mongolianum* (mean: 11.08 ind l^{-1}, 65.73%), *Acanthocyclops vernalis* (mean: 1.26 ind l^{-1}, 7.48%) and *Arctodiaptomus spinosus* (mean: 1.54 ind l^{-1}, 9.17%) were notably higher than at the other sites of the canal. Opposing to this, the mean density of *Simocephalus vetulus*, *Megacyclops viridis* and *Notodromas monacha* increased gradually from the open water to the shore. The mean density and relative frequency of *Ceriodaphnia laticaudata* (mean: 2.6 ind l^{-1}, 11.96 %) and *Daphnia pulex* (mean: 13.05 ind l^{-1}, 59.85 %) were the highest in the middle part of the canal (B8).

Dinka *et al.* (2004) reported similar trends in the aspect of the chemical parameters of the water along the Bozi-canal: for example, the electric conductivity and pH increased from shore to open water. In the canal, the presence of submerged macrophytes and the reduced effect of wind offer favourable life conditions for microrustaceans, but in the dense *Utricularia vulgaris* stands, the density of microcrustaceans, as they are prey animals for the carnivorous *Utricularia*, could notably decrease (Andrikovics *et al.* 1988).

Reed belt

39 taxa were collected at the seven examined sites of the reed belt (N=25). *Macrothrix rosea*, *Scapholeberis mucronata* and the juvenile individuals of *Candona* sp. occurred only in the reed belt sites (Appendix 1). The density of the open lake species was low, these species only occasionally drift into the reed belt. The density and relative frequency of 10 taxa (especially *Ceriodaphnia quadrangula*, *C. reticulata*, *Scapholeberis rammneri*, and *Megacyclops viridis*) were the highest in the reed belt. The mean species richness and diversity were lower than those of the canal, but the ratio of phytophilous taxa (75%)

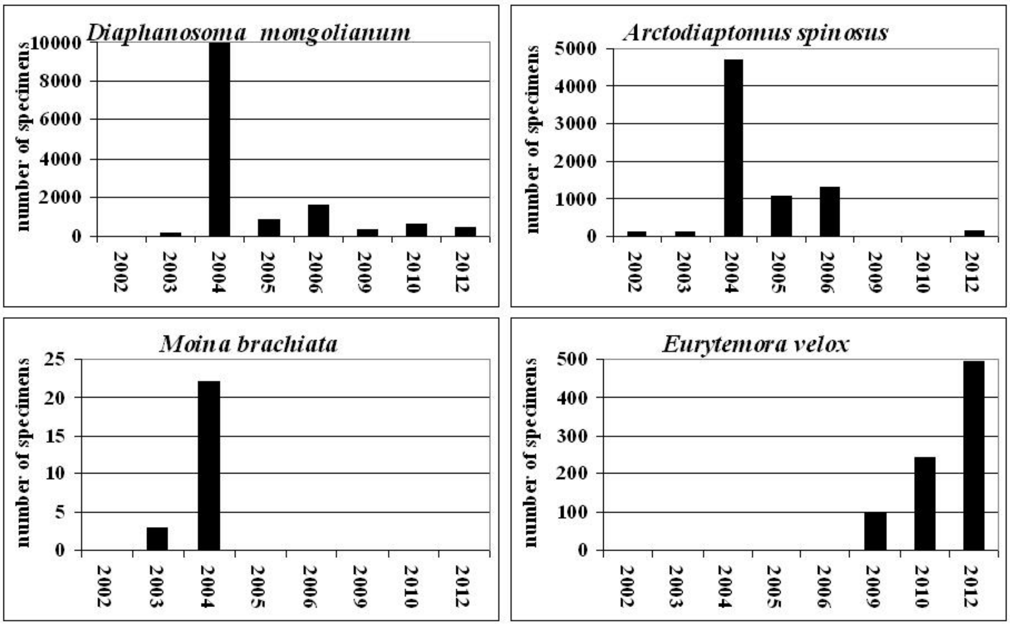

Figure 3. Number per year of collected specimens of *Moina brachiata*, *Diaphanosoma mongolianum* and *Arctodiaptomus spinosus*, the two most frequent species of the lake, and the newly found *Eurytemora velox.*

and ostracods were the highest. The mean density was 5.55 ind l^{-1}, the lowest among the examined habitats. Before our study, quantitative data about the microcrustacean communities of the reed belt in the Lake Fertő were scarce, but the quantitative studies of Forró (1990) from the Austrian side of the lake revealed significantly higher numbers. Kiss (2002b) also reported higher values from the reed belt of the Lake Fehér in Hanság (mean: 83.7 ind l^{-1}).

There were no considerable differences in the species richness (30 and 29 taxa, mean: 8 and 9.15) and Shannon diversity (mean: 1.31 and 1.37) between the healthy (sites 2, 4, 5, 9) and degraded (sites 3, 6, 7) reed stands, but the mean density was higher in the degraded (7.31 ind l^{-1}) than the healthy (3.64 ind l^{-1}) reed stands. The composition of the assemblages was completely different in the healthy and in the degraded reed stands, only 20 out of the 39 taxa occurred at both types of the reed stands. Based on the DCA analysis, the microcrustacean composition of the healthy and degraded reed stands formed well-separated groups (Fig. 4).

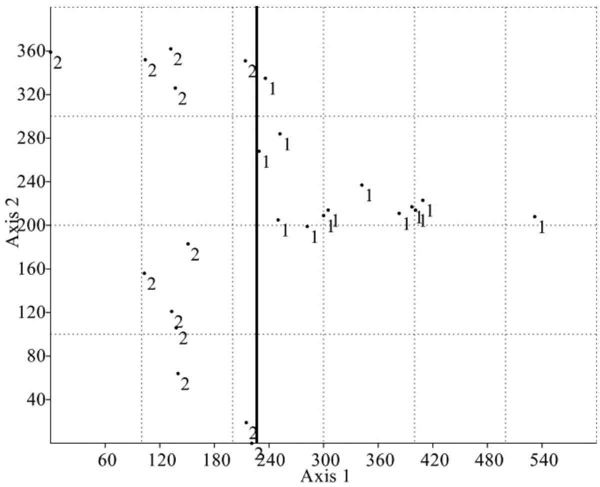

Figure 4. Detrended Correspondence Analysis of the microcrustacean composition in the degraded (1) and the healthy (2) reed stands between 2002 and 2012.

Among cladocerans, *Leydigia acanthocercoides*, *Megafenestra aurita* and *Tretocephala ambigua* were found in the healthy stands, whereas *Daphnia longispina*, *D. magna*, *Macrothrix rosea* and *Polyphemus pediculus* only in the degraded reed stands. *Daphnia magna* (a total of eight specimens) has not been found since the study of Pesta (1954), but in the pools of Seewinkel this species is common (Löffler 1959, Metz & Forró 1991). The density of *Scapholeberis* was notably higher in the degraded reed than in the healthy reed stands. The most significant difference appeared in the Ostracoda fauna: in the healthy reeds 4 taxa (*Cyclocypris ovum, Cypridopsis vidua, Notodromas monacha, Pseudocandona pratensis*), whereas in the degraded reeds 3 taxa (*Candona* sp., *Limnocythere inopinata*, *Potamocypris unicaudata*) occurred. In case of the copepods, *Cyclops vicinus*, *Macrocyclops distinctus* and *Harpacticoida* sp. were reported only from the healthy, whereas *Arctodiaptomus bacillifer* and *Cyclops strenuus* only from the degraded reed stands. These results confirmed the study of Löffler (1979) about the distinct habitat preferences of the species in the reed belt. Kiss (2007b) reported similar significant differences in the composition of assemblages comparing the healthy and degraded macrophyton communities in Lake Fehér.

Löffler (1979) reported 56 taxa (19 Cladocera, 13 Ostracoda and 24 Copepoda) from the reed belt. Out of the 56 taxa 26 also occurred at our sampling sites. Similarly to his findings, the fauna of the reed belt was characterized by a great variety of composition of the communities, but in our study the genera *Diaphanosoma*, *Macrothrix* and *Limnocythere* were not absent from the reed belt. Ponyi & Dévai (1977, 1979) described the assemblages of the various reed communities. In the *Scirpeto-Phragmitetum utriculariosum* reed belt, which is typical in Lake Fertő, the dominance of *Chydorus sphaericus, Pleuroxus aduncus*, *Megacyclops viridis* and *Ceriodaphnia reticulata* was typical, whereas *Ceriodaphnia reticulata*, *Chydorus sphaericus*, *Megacyclops viridis* and *Daphnia curvirostris* were the most frequent species in *Scirpeto-Phragmitetum phragmitetosum*. In our study, the dominance of *Ceriodaphnia* spp., and *Scapholeberis rammneri* has been shown, the density of *Chydorus sphaericus, Pleuroxus aduncus* and *Megacyclops viridis* were insignificant, and *D. longispina* and *D. pulex* were collected instead of *Daphnia curvirostris*.

The typical feature of this habitat is the rich spatial structure, combined with rapidly changing environmental parameters. Food and physical-chemical parameters, especially the fluctuations of oxygen concentration are of great importance to the microcrustaceans. In the reed belt of the Lake Fertő anoxic conditions were often detected (Dinka *et al,* 2004), which together with the accumulation of H_2S have a significant negative influence on the assemblages. Opposing to this, reduced wind effects and water movements, and the presence of emerged and submerged macrophytes offer favourable life conditions to phytophilous and tychoplanktonic species.

Long-term changes in the mincrocrustacean fauna of the Lake Fertő/Neusiedler See

Based on the 15 published faunistic studies of the Lake Fertő, 110 (48 Cladocera, 27 Ostracoda, 35 Copepoda) taxa were reported. This study added *Alona affinis* and *Eurytemora velox*. The results of these studies revealed changes in the fauna of the lake. Daday (1890, 1891, 1897, 1900) found 46 taxa, 16 of these taxa have not been mentioned from the lake later (eg. *Sida crystallina*, *Eurycercus lamellatus*, *Heterocypris salina*). Ponyi & Dévai (1977, 1979) collected 44 (22 Cladocera, 8 Ostracoda, 14 Copepoda) taxa from the Hungarian part of the lake and described the typical assemblages of the different water bodies. In our studies, 71 (30 Cladocera, 17 Ostracoda, 24 Copepoda) taxa were detected between 2002 and 2012 and from this, only 31 taxa were mentioned by Ponyi & Dévai (1977, 1979). Compared to other studies, the number of the collected species was relatively high, but the sampling area was more extensive, and the duration of the survey was longer than those of the other studies. Between 2002 and 2005, we also investigated the inhomogeneous reed patches, situated near the Fertőrákos Bay, after the introduction of pre-treated wastewater. 54 taxa were recorded and out of them 12 were new faunistic records to the fauna of the lake. In the further period of our long-term study between 2005 and 2012, among the new faunistic records, *Macrothrix rosea*, *Pleuroxus truncatus*, *Macrocyclops distinctus* and *Eucyclops macruroides* have also been found in the other water bodies of the lake. *Macrothrix rosea* (Löffler 1959, Metz & Forró 1991) and *Eucyclops macruroides* (Löffler 1959) were collected in the nearby Seewinkel, but the cosmopolitan *Macrocyclops distinctus* and the holarctic *Pleuroxus truncatus* have not been detected from the area of the Fertő-Hanság yet. The density of the newly detected species was usually very low, indicating the lack of stable populations and the possibility of passive dispersion by waterbirds.

Similarly to the results of Ponyi & Dévai (1977, 1979), the composition of assemblages differed completely in the various habitats. Compared to the Cladocera and Copepoda fauna of the lake, the Ostracoda fauna is less known. Among the 17 detected Ostracoda species of our study, *Potamocypris unicaudata* was first mentioned from the Lake Fertő by Ponyi & Dévai (1977, 1979), and Löffler (1959) found this species in some pools of the Seewinkel. Instead of *Limnocythere sanctipatricii* (Daday, 1900) later *Limnocythere inopinata* was mentioned (Schiemer *et al.* 1969, Jungwirth 1979), which is an indicator of high alkalinity (Löffler 1990). In the Austrian part of the lake, *L. inopinata* showed a distinct distribution pattern (Jungwirth 1979), but in the course of our study, this species occurred only in 2012, and the collected 57 specimens were found in the inner ponds (sites 41, 42, and 47) and the reed belt (site 3). *L. sanctipatricii* seems to have been restricted to oligotrophic habitats (Meisch 2000), and along with the eutrophication processes apparently disappeared from the lake. *Pseudocandona pratensis* was first mentioned by Löffler (1979), just as *Candona pratensis*. Kiss (2007a) reported four Ostracoda species (*Candona weltneri*, *Fabaeformiscandona fragilis*, *F. holzkampfi*, *Pseudocandona compressa*) for the first time from the inhomogeneous reed patches, after the introduction of pre-treated wastewater. *Candona weltneri*, *Fabaeformiscandona fragilis* and *Pseudocandona compressa* are common ostracods in the reed belt of the neighbouring Lake Fehér in the Hanság region (Kiss 2007b), while *Fabaeformiscandona holzkampfi* was described from Lake Balaton (Daday 1903) and Lake Velence (Györe 1985).

From the cladocerans, *Moina brachiata* was only found in two years (2003, 2004) of our study and of very low density: only 25 specimens were collected (Fig. 3). This species has been mentioned earlier by Daday (1890, 1891) and Forró & Metz (1987) and *M. brachiata* was very abundant until 1950 (Pesta 1954). Herzig (1979) and Löffler (1979) have not found *M. brachiata* in the Austrian part of the lake, but in the pools of the neighbouring Seewinkel this cladoceran is one of the most abundant crustaceans (Löffler 1959; Metz & Forró 1991). According to Herzig (1979) *M. brachiata* formerly inhabited the lake, but disappeared in the past forty years because of the increasing water level and decreasing salt concentration of the water. *Diaphanosoma* has taken over the niche previously occupied by *Moina*.

In our survey the most frequent *Daphnia* species was *D. pulex* which accounted for an average of 34 percent in the assemblages of the Bozi-canal. Pesta (1954) described this species as a typical member of the ponds in the reed belt, and it was very rare in the plankton of the open lake. Since 1975, *D. pulex* has been replacing *D. longispina* in the open lake community (Herzig 1979). According to our study supported by the results of Pesta (1954), *D. pulex* had a distinct distribution pattern and appeared only in the sampling sites of the reed belt. In the Bozi-canal and the open water this species did not occur. *D. longispina* appeared in all types of water bodies, but its density was very low everywhere.

Ponyi & Dévai (1977, 1979) revealed that since Daday the species richness of Copepoda showed an increasing tendency. Daday (1891) mentioned 10 species, while Pesta (1954) 15, Ponyi & Dévai (1977, 1979) 14, and Löffler (1979) 24 species. Forró & Metz (1987) reported 14 species and detected *Cyclops vicinus* for the first time. In our study, between 2002 and 2012, 24 taxa were recorded, however in these studies the number of sampling sites and the duration of the survey were different.

Herzig (1979) established a general decline in the *Cyclops* genus in the assemblages of the open lake. He recorded only 3 species (*Acanthocyclops robustus*, *Mesocyclops leuckarti*, *Thermocyclops crassus*) and the majority of the animals found were in the nauplius stage. The reasons for this phenomenon were supposedly the wind situation and the rapid decrease of the macrophytes in the Austrian part of the lake (Schiemer & Prosser 1976). In our investigation, 10 *Cyclops* species were recorded from the open lake and 9 from the inner ponds. Similarly to the results of Herzig (1979) the density of the species was insignificant, except for *Acanthocyclops vernalis*. The decline of macrophytes has not been confirmed in the Hungarian part of the lake, but the extreme wind effects could actually decrease the abundance of *Cyclops* species.

CONCLUSION

Between 2002 and 2012, 53 taxa (24 Cladocera, 9 Ostracoda, 20 Copepoda) were recorded from different water bodies of the Lake Fertő. Thus, the microcrustacean fauna of the lake increased to 112 (49 Cladocera, 27 Ostracoda, 36 Copepoda) species together with *Alona affinis* and *Eurytemora velox*, detected for the first time in the lake. Since the study of Ponyi & Dévai (1977, 1979), there were no intensive, long-term studies in the Hungarian part of the lake investigating the composition and spatial differences of the three microcrustacean groups. In our studies, we confirmed some faunistic changes in the microcrustacean fauna of the lake, which were established in the 1970s, especially the significant reduction of *Moina* and *Cyclops* populations in the assemblages of the open lake.

Significant differences were revealed in the community parameters between the different water bodies of the lake. The mean density of the assemblages was significantly higher in the inner ponds and canal sites than in the open water and reed belt sites. The species richness and the diversity of the assemblages were the highest in the Bozi-canal. This specific fragmentation caused by the canal system may be supporting high habitat diversity.

The microcrustacean fauna of the Lake Fertő has been investigated for approximately 120 years. On the basis of the results the fauna of the lake changes dynamically, some species disappear, old species reappear and new species occur. These changes support the concept of high instability and spatial variability of the lake habitats which are partly consequential to the extreme shallowness of the Lake Fertő.

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Appendix 1. Microcrustacean species frequencies in the different water bodies (O W – open water, I P – inner ponds, B C – Bozi canal, R B – reed-belt) and lists of species in the examined years. (WP = Wastewater Project: The species which only occurred in the inhomogeneous reed patch, after the introduction of pre-treated wastewater in 2004 (Kiss 2007a)).

	O W	**I P**	**B C**	**R B**	**2002**	**2003**	**2004**	**2005**	**2006**	**2009**	**2010**	**2012**
	N=33	N=41	N=22	N=25	N=9	N=4	N=36	N=10	N=14	N=14	N=14	N=20
CLADOCERA												
Alona affinis (Leydig, 1860)		<0.01								X		
Alona costata Sars, 1862			<0.01	<0.01						X		
Alona intermedia Sars, 1862							WP					
Alona rectangula Sars, 1862	<0.01	<0.01	<0.01	0.03	X		X	X	X		X	X
Alonella excisa Fischer, 1854							WP					
Alona nana Baird, 1843							WP					
Bosmina longirostris (O. F. M., 1785)	0.03	0.37	0.02	<0.01	X	X	X	X	X	X	X	X
Bunops serricaudata Daday, 1888							WP					
Ceriodaphnia laticaudata P. E. M, 1867	<0.01	<0.01	0.06	0.03					X	X	X	
Ceriodaphnia quadrangula (O. F. M., 1785)	0.01	0.08	0.04	0.13	X		X	X	X	X	X	X
Ceriodaphnia reticulata (Jurine, 1820)	<0.01	<0.01	0.04	0.14			X	X	X	X	X	X
Chydorus sphaericus (O. F. M., 1776)	<0.01	<0.01	0.02	0.05	X		X	X	X	X	X	X
Daphnia curvirostris Eylmann, 1878							WP					
Daphnia pulex Leydig, 1860			0.34	0.07	X		X	X	X	X		
Daphnia longispina O. F. M., 1785	<0.01	<0.01	0.01	<0.01			X	X		X	X	X
Daphnia magna Straus, 1820		<0.01		<0.01			X		X			
Diaphanosoma mongolianum Uéno, 1938	0.49	0.17	0.28	0.02	X	X	X	X	X	X	X	X
Leydigia acanthocercoides (Fischer, 1854)			<0.01	<0.01			X				X	
Macrothrix hirsuticornis N. & B. 1867			<0.01		X		X					
Macrothrix rosea (Liévin, 1848)				<0.01			X					
Megafenestra aurita (Fischer, 1849)			<0.01	<0.01			X		X	X	X	
Moina brachiata (Jurine, 1820)	<0.01	<0.01	<0.01			X	X					
Oxyurella tenuicaudis Sars, 1862							WP					
Pleuroxus aduncus (Jurine, 1820)	<0.01		<0.01	<0.01	X		X	X	X	X	X	X
Pleuroxus truncatus (O. F. M. 1785)	<0.01									X		
Polyphemus pediculus (Linné, 1761)		<0.01	<0.01	<0.01			X	X			X	X
Scapholeberis mucronata (O. F. M., 1785)				<0.01						X	X	
Scapholeberis ramneri D. & P., 1983		<0.01	<0.01	0.14	X	X	X	X	X		X	X
Simocephalus exspinosus (Koch, 1841)							WP					
Simocephalus vetulus (O. F. M., 1776)	<0.01	<0.01	0.02	0.02	X		X	X	X	X	X	X
Tretocephala ambigua (Lilljeborg, 1900)			<0.01	<0.01						X		

OSTRACODA												
Candona neglecta Sars, 1887							WP					
Candona weltneri Hartwig, 1899							WP					
Candona sp. juv.				<0.01		X	X	X				X
Candonopsis kingsleii (B & R, 1870)							WP					
Cypria ophtalmica (Jurine, 1820)	<0.01		<0.01				X	X	X			
Cypris pubera O. F. M., 1776							WP					
Cyprois marginata (Straus, 1821)							WP					
Cyclocypris laevis (O. F. M., 1776)	<0.01		<0.01				X	X	X			
Cyclocypris ovum (Jurine, 1820)	<0.01	<0.01	<0.01	<0.01	X		X	X		X	X	
Cypridopsis vidua (O. F. M., 1776)				<0.01							X	
Fabaeformiscandona fabaeformis (Fischer, 1851)							WP					
F. fragilis (Hartwig, 1898)							WP					
F. holzkapmfi (Hartwig, 1900)							WP					
Limnocythere inopinata (Baird, 1843)		<0.01		<0.01				X				X
Notodromas monacha (O. F. M., 1776)			<0.01	<0.01			X	X	X	X	X	
Potamocypris unicaudata Schäfer, 1943		<0.01		<0.01				X				X
Pseudocandona compressa (Koch, 1838)							WP					
Pseudocandona pratensis (Hartwig, 1901)	<0.01			<0.01			X			X	X	
COPEPODA												
Acanthocyclops vernalis (Fischer, 1853)	0.09	0.05	0.03	0.01	X	X	X	X	X	X	X	X
Arctodiaptomus bacillifer (Koelbel, 1885)	<0.01	<0.01		<0.01			X					X
Arctodiaptomus spinosus (Daday, 1891)	0.32	0.11	0.06	0.09	X	X	X	X	X	X		X
Cyclops strenuus Fischer, 1851	<0.01	<0.01	<0.01	0.01	X		X	X				
Cyclops vicinus Uljanin, 1857	<0.01	<0.01	<0.01	<0.01			X	X			X	X
Diacyclops bicuspidatus (Claus, 1857)	<0.01	<0.01			X		X					
Ectocyclops phaleratus (Koch, 1838)			<0.01					X				
Eucyclops macrurus (Sars, 1863)			<0.01		X		X	X				
Eucyclops macruroides (Lilljeborg, 1901)			<0.01					X				
Eucyclops serrulatus (Fischer, 1851)	<0.01	<0.01	0.01	0.04	X		X	X	X	X	X	X
Eurytemora velox (Lilljeborg, 1853)	<0.01	0.02		0.04						X	X	X
Macrocyclops albidus (Jurine, 1820)		<0.01	<0.01				X	X				
Macrocyclops distinctus (Richard, 1887)	<0.01		<0.01	<0.01	X						X	
Macrocyclops fuscus (Jurine, 1820)		<0.01	<0.01				X	X				
Megacyclops viridis (Jurine, 1820)	<0.01		<0.01	0.07			X	X	X	X	X	
Mesocyclops leuckarti (Claus, 1857)	<0.01	<0.01	0.01	0.02	X		X		X	X	X	X
Microcyclops varicans (Sars, 1863)			<0.01					X	X			
Paracyclops affinis (Sars, 1863)							WP					
Paracyclops fimbriatus (Fischer, 1853)	<0.01									X		
Thermocyclops crassus (Fischer, 1853)	<0.01	0.15	<0.01	<0.01		X	X		X	X		X
Thermocyclops dybowskii (Lande, 1890)							WP					
Harpacticoida sp.	<0.01			<0.01							X	
Number of taxa	**30**	**29**	**38**	**39**	**19**	**8**	**37**	**31**	**23**	**27**	**27**	**22**